Development and Validation of New Dual-Doppler Analysis Techniques with Emphasis on the Vertical Velocity Problem

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LONG TERM GOALS

Our longterm goal is to develop new dual-Doppler analysis techniques with an emphasis on improving estimates of the vertical velocity field.

OBJECTIVES

Our main objective is to use a dynamical constraint (vertical vorticity equation) to improve dual-Doppler analyses of the vertical velocity field over those obtained with traditional methods.

APPROACH

This work involves the development and testing of three new techniques (based on variational methods) to analyze the wind and vertical velocity field from dual-Doppler radar data. These methods all rely on the Boussinesq form of the vertical vorticity equation imposed as a weak or strong constraint, with and without the anelastic mass conservation equation (Mewes and Shapiro 1999). In each method the relevant Euler-Lagrange equations are solved numerically (they are either elliptic equations or can be made elliptic by applying a small amount of spatial smoothing). These methods are designed to contend with the irregular lower/upper boundaries of the data region -- in essence, the methods seek to derive the "optimal" boundary condition for the vertical velocity field on these irregular boundaries. These techniques are being tested on simulated radar data sampled from high resolution runs of a numerical weather prediction model, the Advanced Regional Prediction System (ARPS).

The PI (Prof. Alan Shapiro) supervises one doctoral student, John Mewes, on this effort. Additional assistance is provided by research associate Paul Robinson at the Coastal Meteorology Research Program (CMRP) at the University of Oklahoma.

WORK COMPLETED

This past year has seen the continued testing of new vertical velocity analysis methods with simulated high resolution thunderstorm data from the ARPS model. Tests focussed on the impacts of different spatial and temporal data coverage at different times in the life-cycle of the simulated storm (early stages, rapid growth, mature, decay). Simulated data were rejected beneath a variety of levels (e.g., 0.5

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14. ABSTRACT
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15. SUBJECT TERMS

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km, 1.0 km, 1.5 km) to mimic the spatial availability of real radar data under various scenarios. Separate experiments were run with simulated data provided at 5 minute intervals and at 90 second intervals to mimic the temporal resolution of radar data with WSR-88D radars and research radars, respectively. Additional tests explored strategies for rejecting data based on the magnitude of the local wind shear (which played a key role in the error analysis). We have also examined the Doppler-on-Wheels squall line data gathered last year over the ARM/CART site in northern Oklahoma. Unfortunately, the problem of attenuation in heavy rain was particularly severe for one of the radars and there was little dual-Doppler data coverage. The new methods and highlights from the tests with the simulated data are described in the manuscript, "On use of the vorticity equation in dual-Doppler analysis of the vertical velocity field," which was recently submitted to the Journal of the Atmospheric Sciences.

RESULTS

Results with ARPS-simulated data of a splitting thunderstorm show that use of the vorticity equation can greatly improve vertical velocity field estimates over traditional methods. The improvement requires that data be available at least as often as the 5-6 minute scanning time of NEXRAD radar, with 1-2 minute scanning times being optimal. The improvements over the traditional method are greatest in cases where larger amounts of data are missing at lower levels. Tests with the 5-6 minute data (coarse time resolution) showed the new methods performed better than the traditional method throughout the life-cycle of the storm with the exception of a short (5-10 min) time period of rapid storm growth where the traditional method was slightly better. The new methods yielded especially good results at all times (compared to the traditional method) in the case where high time resolution data (90 sec) were available. The filtering effect of the new methods insured that the results were not very sensitive to random errors.

IMPACT/APPLICATIONS

Improved dual-Doppler wind analyses -- and especially improved vertical velocity analyses -- have a potentially wide-ranging impact on a variety of meteorological research and on operational meteorology. Improved wind estimates and associated improvements in thermodynamic field estimates can lead to improved understanding of short time scale mixing processes and complex structures in the atmospheric boundary layer, and can potentially lead to improved boundary layer parameterizations in mesoscale, regional and climate models. Dual-Doppler analyses can also aid in the identification and characterization of boundary layer structures associated with the onset of severe weather, and lead to improved conceptual models of convective phenomena such as squall lines, thunderstorms, and microbursts. Dual-Doppler wind and thermodynamic analyses can also be used as high resolution data sources for convective scale and mesoscale numerical weather prediction models. Single-Doppler velocity retrieval studies also rely on dual-Doppler wind analyses for verification.

TRANSITIONS

Previously, results of this work have been presented at the 29th International Conference on Radar Meteorology (Mewes and Shapiro 1999). We would like to present further results at next years radar conference. Additionally, a manuscript on this subject has been submitted to the Journal of the Atmospheric Sciences.

RELATED PROJECTS

This AASERT grant is related to the parent grant funded by the DoD (ONR): "MURI: Remote Sensing and Prediction of the Coastal Marine Boundary Layer," Grant N00014-96-1-1112, also known as the Coastal Meteorology Research Program (CMRP). The lead PI is Brian Fiedler at the University of Oklahoma School of Meteorology. Co-PIs are: Yefim Kogan, Alan Shapiro, Vince Wong and Joshua Wurman.

REFERENCES

Mewes, J. J. and A. Shapiro, 1999: Dual-Doppler analysis using the anelastic vertical vorticity equation. *29th Intl. Conference on Radar Meteorology*, Montreal, Quebec, Canada, Amer. Meteor. Soc., 33-36.

PUBLICATIONS

Mewes, J. J. and A. Shapiro: On the use of the vertical vorticity equation in dual-Doppler analysis of the vertical velocity field. *J. Atmos. Sci.* (submitted)